U. S. DEPARTMENT OF COMMERCE
DANIEL C. ROPER, Secretary
BUREAU OF FISHERIES
FRANK T. BELL, Commissioner

Fishery Circular No. 26

INSTRUCTIONS FOR CONDUCTING STREAM AND LAKE SURVEYS

By H. S. DAVIS

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1938

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INSTRUCTIONS FOR CONDUCTING STREAM AND LAKE SURVEYS [1]

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INTRODUCTION

It is now generally recognized that if we are to realize the greatest benefits from our inland waters it will be necessary to adopt a systematic plan of fish management. Such a plan should include a com-

[1] Fishery Circular No. 26. Approved for publication April 1, 1938. Revised from "Instructions for Stream and Lake Survey Work" by A. S. Hazzard (1935).

prehensive stocking program adapted to the needs of each individual body of water, the control or elimination of pollution, the development and maintenance of proper physical and chemical conditions, and the adoption of regulations designed to insure to the public the greatest possible returns in recreational and food values, consistent with a sustained yield. However, before such a program can be put into effect it is necessary to have certain basic data and general information on each body of water. It is the purpose of these instructions to indicate the information that will be of greatest value, and to outline the methods to be employed in obtaining this information.

It is important to bear in mind that something other than the routine collection of data is necessary in order to present a clear picture of conditions. Special attention should be paid to the human factor involving such matters as heavy fishing, the presence of lawless elements, and the suitability of fishing laws. Where such laws are unsuitable, or not enforced, it may be inadvisable to attempt any management program until these obstacles have been removed.

It should be emphasized at this point that our knowledge of the basic factors involved in the production of fish and other aquatic organisms is so limited and fragmentary that it is not possible to fully utilize all the information collected. For example, we do not know enough concerning the life histories of our principal game and forage fishes to state with certainty the species that will do best under a given set of conditions. However, we do have sufficient knowledge, which is being constantly augmented, to enable us to recommend the planting of fish that should thrive under these conditions and to rule out other species which we know would be unsuitable.

Furthermore, we know little concerning the extent to which fish are able to utilize the available food, and how many fish a given body of water can support without their suffering from overcrowding. The loss which results when planting various sizes of fish is not definitely known. The inter-relationships of various species of fish are poorly understood, and there are many other unknowns. However, despite our limited knowledge, it is evident that the information obtained by a comprehensive survey will make it possible to adopt measures that are much superior to the haphazard methods of stocking formerly employed.

In addition to collecting the routine data called for in the blanks, the survey parties will have opportunities to collect data for special research problems, and these should be made a part of the work. They include such matters as the length-weight relationship of various species under different conditions, age determinations, population studies, and data on geographic distribution. For this reason instructions are given for taking measurements and methods are given for collecting other data not called for in the field blanks.

The surveyor should not collect data blindly but should look at each body of water as a new problem. Each should be compared with other waters with which he is familiar and their resemblances and differences noted. He must be constantly on watch for anything affecting fish life in order to bring all factual information obtained to focus on the final stocking, or other recommendations.

Although it is hoped that these instructions may be widely applicable, they are intended primarily for an extensive survey of some

region or drainage basin, and not for an intensive or complete study of any given lake or stream. They are drawn up for the use of small survey parties which will gather the information in the field and record it on the Bureau of Fisheries forms reproduced on pages 45–52. The various headings on the forms are taken up in order and the method for taking data fully described.

STREAM SURVEY

PLANNING THE WORK

Prior to entering the field the leader and his assistants should study carefully all maps which are available for the area in which the work is to be carried on. Tentative camp sites should be chosen, keeping in mind the mileage of streams and lakes which can be worked most efficiently from each as a base. The working distance from any camp will vary considerably, depending upon the nature of the country and the number and condition of the roads. In general, it does not pay to work streams or lakes which are farther than 25 miles from any camp. Where roads are lacking, or poor, this working distance may be reduced considerably. On the other hand, in the case of a few isolated waters, it may be more economical to travel a considerable distance to reach them than to take the time to make a new camp for only a day or two of work.

A tentative schedule for the work should be drawn up several weeks in advance, even though numerous changes may be necessary later. The importance of careful planning cannot be overemphasized.

Each day, before starting into the field, the work for that day should be outlined and assigned among the workers. This is essential in order to avoid overlapping and excessive mileage.

Designating waters.—Because of the fact that many waters are still unnamed, and because the same name is frequently given to a number of different streams in the same region, it is necessary to use some method of designating the waters which will not be subject to alteration. Some such system is also desirable as an aid to filing the data for reference in the office.

For this purpose it is probably best to use the township and range designations on the Forest Service maps, together with the name of the stream or lake. Where unnamed lakes or streams are found in any section, they should be designated by numbers on the maps and the range, township, and number placed in front of the stream or lake blank in the space following the word number. New York State uses a system in which the tributaries are numbered in order from the mouth up, and the lakes along each stream system are similarly designated. When an entire river system is being studied this method is very satisfactory.

When the Bureau of Fisheries survey form is being used, under "River system" indicate the name of the principal drainage system in which a lake or stream is found. For example, if a lake empties into a stream, which in turn enters the North Fork of Snake River, the river system designated should be "Snake." In other words, this refers to the principal drainage basin of the region.

In the space following "map" indicate whether it is a Forest Service map by the letters "U. S. F. S.," Geological Survey by "U. S. G. S.," or by suitable abbreviation for what other map is being used. Following the words "tributary to" should come the name of the stream or lake to which the water being designated is immediately tributary.

"*Stream section*" refers to the portion of the stream which is covered in the particular survey sheet. For example, it may be necessary to fill out three or four sheets for one of the larger streams which is being studied. If the particular survey blank covers the lower section, say from the mouth of Cottonwood Creek to mouth of E. Canyon Creek, this designation should be placed here. The length of section should be determined by using the map tracer and by referring to the scale of miles on the map. This should be determined after returning to camp.

"*Notes—Sketches*" should include any miscellaneous notes for which there is no allotted space in the blank. In addition there should be a sketch of all sections studied with the location of all stations where observations were made. Any posted sections should also be indicated with the name of the owner.

In studying lakes and ponds a careful sketch should be made to show the location of stations, entrance and outlet of tributary streams, soundings, and principal weed beds. North should be indicated by an arrow. When the lake is too large to allow for all this information a separate blank should be used for this purpose and enclosed with the regular lake survey sheet describing this water.

METHOD OF STUDY

In a routine survey it will not be possible to follow every stream from mouth to source. However, observations should be taken sufficiently close together so that a clear picture will be obtained of the stream. Much will depend upon the character of the country, and the character of the stream, as to how frequent the stations should be. In general, readings should be taken at least every 3 miles. If it is known or surmised that the character of the stream undergoes frequent changes in this section, a number of readings in this 3-mile stretch might be necessary. For example, if the map shows a number of good-sized tributaries entering this section, or indicates the presence of a dam or falls, the location of a mine, or other possible source of pollution, it may be necessary to cover the entire 3 miles carefully. In such a case both men should leave the car and approach the stream at the lower end and make a complete station reading. One man should then proceed upstream on foot making notes of any changes in conditions and should meet the other man who will drive to a point designated on the map. In more settled regions the best plan is for one man to start in at the lower end and work upstream for a distance of several miles and pick up the car at a point previously agreed upon. In the meantime the other man will have been working in the middle section and will follow up to the next designated point. There he will pick up the car and drive to the source of the stream where his companion will meet him.

Character of the watershed.—Underscore the descriptive terms which apply to the section described in each blank. It is possible that

several terms will be applicable to one section, but only those terms should be underscored which are most characteristic of the region. For example, it might be possible that all of the terms listed could be applied to a certain section of some particular stream. However, if the section is primarily mountainous and wooded, these terms should be underlined even though small open or cultivated patches are found along the stream. The letters U, M, or L should be inserted below the underlined terms, indicating conditions in upper, middle, or lower regions.

FIGURE 1.—A New England trout stream.

Character of subsoil, bedrock, and dip of strata.—It is believed that the nature of the underlying terrain has an important bearing upon both the type of bottom and the character of the pools. In this space record the character of the subsoil as exposed by the stream, indicating whether it is of glacial till, alluvium, or bedrock. In the latter case state the approximate dip of the strata and type of rock.

Source.—Streams may arise from springs, glaciers, snow, or surface run-off. The formation of new channels, due to mining activities, is also quite common in some parts of the country.

Barriers.—The location and height of any dams, natural falls, or other obstructions to fish movement, should be clearly indicated by a short line drawn across the stream on the map which will accompany the final report. A brief description of the location and the height should be given in the space provided by this blank. These barriers are often of great importance, not only in preventing the migration of fish but also in preventing the access of less desirable fish into the upper waters of the stream. It frequently happens that a permanent barrier can be made a dividing line in stocking certain species which are not compatible. A supplementary

sheet should be used to describe barriers or diversions of unusual importance.

Diversions.—The points where canals for irrigation, power, or other purposes leave the stream should be clearly indicated on the map by an arrow directed from that point, showing the canal distribution. The exact position, approximate capacity, purpose of the diversion, and whether or not it is screened, should be given in the blank.

Springs.—The exact location of each spring should be shown on the map by a circle with a dot in the center. The location, flow, and temperature should be given. One of the objectives of a survey is to locate favorable sites for rearing ponds and hatcheries. It is important that a full report on any possible source of suitable water be given. These sites should be recorded on the map and a chemical analysis of the water, including dissolved oxygen, carbon dioxide, pH, and carbonates should be made. Any information from local residents, Forest Service men, or others concerning fluctuation throughout the season, should be recorded.

Tributaries.—In this space should be noted the number and size of tributary streams which enter the section covered by the blank. A separate sheet should be made out for each of these tributaries having a flow of 50 gallons per minute or more. A lower reading, taken within a few hundred yards of the mouth, should be made on each tributary stream. If the stream is large enough for stocking purposes, other readings are desirable and should be made if directed by the leader. Such streams should be investigated as to possibilities for natural propagation.

Volume of flow.—Record in c. f. s. (cubic feet per second) the volume of flow where it is 1 foot per second or greater. Streams of less than 1 cubic foot per second should be described in gallons per minute. One cubic foot per second is equal to approximately 450 gallons per minute. Embody (1927) gives the following formula for determining the approximate flow of a stream:

$$R = \frac{W\,Da\,L}{T}$$

In which R is equal to the rate of flow in c. f. s.; W is average width; D is average depth in feet; L is the length of the section measured; a is a constant for correction of stream velocity; and T is the average time in seconds required for a float to traverse the distance L.

If the bottom is rough and strewn with rocks and coarse gravel, a should be taken as 0.8; if the bottom is smooth (of mud, sand, hardpan, or bedrock), 0.9 is used as the constant.

A straight section of the stream is chosen where there are few obstructions to the current's flow, 100 feet is measured off, and the average width and depth are taken. A float is then dropped in at the upper end of the section and timed to the lower end. The average of three tests with the float is recorded as the time.

Fluctuation in volume should be recorded in terms of cubic feet per second, or gallons per minute, where these data are available. The principal streams in the West are gaged by the water users and accurate information can be secured as to their fluctuation. It is the duty of the party to make the contacts necessary to secure this information.

State the condition of water at the time of the reading. If the reading is taken during a period of high water, this should be noted. Likewise, a condition of extremely low water, or what appears to be the average, should be recorded.

Gradient.—The gradient of the stream should be expressed in terms of the number of feet which it falls per mile if this information is available on the maps or elsewhere. Otherwise it should be expressed by the term "steep," if the stream approaches a torrential nature, "moderate," if a succession of pools and riffles are found, and "slight," if the stream has sluggish stretches.

Velocity.—Describe as sluggish, moderate, swift, or torrential. Torrential streams are those which flow over steep slopes with few if any pools in their course. Such streams support too few fish to merit consideration for stocking.

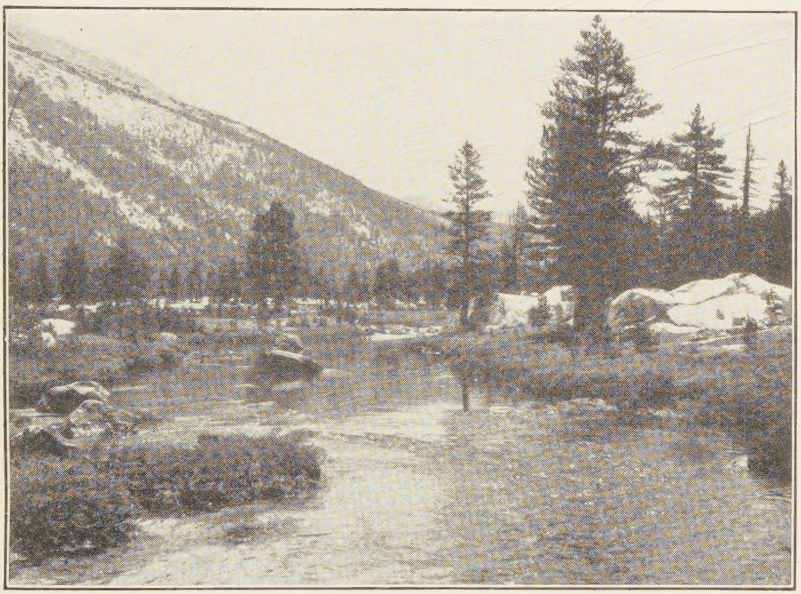

FIGURE 2.—A trout stream in the Sierras of California.

Station.—The exact point where readings on the upper, middle, or lower section of the stream are taken should be marked on the map by a circle with a cross in it. Stations should be selected to represent as near average conditions as possible. They should be indicated on the sheet by reference to some definite point such as "main highway crossing," "bench mark," or the distance from the mouth of a tributary stream. The position of every station is of the utmost importance, and the exact location should be clearly indicated on the survey sheet.

Average width and depth.—These should be determined by a series of measurements at points selected to represent average conditions. At least three measurements of width should be taken in each section. At these points the depth should be secured at one-half of the distance between one shore and the middle of the stream, at the middle, and at a point midway between the middle and the opposite side. Obviously the width and depth will vary, depending on the height of the water.

The condition of the stream in this respect should be indicated in the proper place. The average depth is determined by adding the readings and dividing by the number taken.

Color and turbidity.—Color is expressed as "white," "light brown," and "dark brown." The majority of waters are white, although occasionally boggy lakes or streams draining swampy areas show a more or less marked brown color. Turbidity is expressed in the terms "clear," "murky," and "muddy"; clear if bottom is distinctly seen through 4 or more feet of water, murky if indistinct at from 1 to 4 feet of water, muddy if indistinct at less than 1 foot.

Alkalinity.—The methyl orange and phenophthalein alkalinity, as well as the pH, should be taken at one station in each section of stream. Determinations should be made according to directions in the appendix, and should be recorded on the supplementary chemical blank.

Temperature.—Temperature of the air should be taken while standing in the stream with back to the sun, holding the thermometer at forearm's length at the level of the waist with the bulb in the shade of the body. It may require 4 or 5 minutes to register the temperature of the air. The observer should be certain that the thermometer bulb is dry. Water temperature is taken by inserting the bulb below the surface and by reading the temperature while it is held in this position. Usually 1 minute is all that is necessary for this record.

The "hour" and "sky" when these temperatures are taken should be recorded. The terms "clear," "partly cloudy," and "overcast" are used to express the condition of the sky. Also note if taken after an unusually hot or cold night, following rain, etc.

Pools and shelter.—To make a permanent abode for fish, a body of water must afford shelter. In the case of a stream which from its summer temperature seems suitable for trout, shelter is of great importance for two principal reasons: (1) for concealment, and (2) for relief from the current. In the case of quiet, shallow streams, hiding places are of primary importance. With rapid streams, shelter from the current becomes necessary.

Pools are of great importance to a stream. They may afford concealment, relief from current, depth, and suitable environment for growth of large fish; or they may be so open, shallow, and exposed as to afford little or no shelter of any sort and cause the stream to warm too rapidly. A typical good pool may be taken as one with a rapid current entering at the head, with good depth and eddies, and with the current extending along the surface for a considerable distance into the pool. In such cases there will be relief from the current not only in the obviously quiet places, but also under the rapid current, which offers a large area for concealment even though boulders or other objects under which trout may hide are not in evidence. In quiet streams there will not be sufficient surface agitation to afford much concealment. In these, depth or such protection as that provided by overhanging banks, logs, roots, boulders, or vegetation is necessary to make a pool of value.

Pools may be graded as to size into "small pools," the length or width of which is about equal to the width of stream, and "large pool," the length or width of which is considerably greater than the

width of stream. In some cases, especially for bass streams, it may be advisable to add a third class, "very large pools," for pools several times as long, or wide, as the width of stream.

As to quality, pools may be graded as "good" if they afford excellent shelter, either by reason of broken surface, depth, overhanging banks, roots, logs, boulders, etc., or abundant vegetation, which latter probably also means high food productivity; "fair" if they afford appreciable but limited shelter; and "poor" if they afford little or no shelter, such as exposed shallow pools without plants, but be sure there is no shelter under the bank. If the area in pools about equals the riffle areas it is believed that ordinarily this represents a proper balance. Note the relative areas.

Riffle areas are of value not only for aeration, and as special sources of food production, but frequently also as providing holding areas for fish. Broken water, as noted above, affords most excellent concealment. Relief from current may be afforded by large stones or other obstructions and by "pockets" either along the shore or out in the stream. Such an area constitutes a special type of environment, and frequently provides excellent fishing. Note whether riffle areas are shallow or deep, and whether sheltering boulders or pockets are abundant, fairly abundant, scarce, or absent, as well as the extent of riffles as compared to pools.

Bottom.—Describe pool and riffle bottom separately in the spaces provided. Record or estimate the percentages of mud, silt, sand, clay, marl, hardpan, gravel (coarse or fine), rubble, or bedrock, which are present. The type of bottom of the stream is of greatest importance for a number of reasons. Needham (1929) and later Pate (1932) found the following types of bottom productive in the order listed: Silt, small rubble, large rubble, coarse gravel, fine gravel, and sand. In his 1933 results Pate has found rubble to be more productive even than silt bottom. In his summary of these quantitative food studies for a 4-year period, Pate records the following yields for different types of bottom:

	Grams per sq. ft.
Silt	3.07
Rubble	2.47
Large rubble	1.55
Small rubble	3.55
Coarse gravel	1.51
Fine gravel	.93
Sand	.1

Apparently the same type of soil which produces luxuriant crops in our river valleys is also most productive of water plants such as algae, water cress, and various pondweeds. As a result this soil supports the heaviest population of fish food, since these organisms are directly or indirectly dependent upon the aquatic plants for their food and shelter.

"Bedrock" refers to the solid, immovable underlying strata, "hardpan" consists of hard deposits of clay which have been exposed by water action, "clay" is a familiar type of soil composed largely of hydrous aluminum silicate, "silt" is a fine earthy sediment carried and deposited by water, and "marl" is a white calcareous material consisting largely of inorganic material as contrasted to "muck," which consists principally of fine, partially decomposed organic material.

"Detritus" is composed of broken or divided organic substances such as bits of leaves, twigs, bark, remains of water plants, etc., and usually comprises the surface layer of muck. Detritus is frequently found on pool bottoms or in the shelter of obstructions to the current. It appears to provide excellent shelter and food for many stream organisms such as midges, stickcaddis, worms, nymphs of dragonflies, and certain stoneflies. "Sand," as here classified, consists of rock particles finely ground and ranging in size from almost microscopic to about one-eighth inch in diameter. "Fine gravel" runs from about one-eighth inch to about the size of a marble, or one-half inch. "Coarse gravel" runs from stones the size of marbles to 3 inches. "Rubble" includes rough, irregular stones ranging in size from 3 to 12 inches. "Small boulders" consist of stones 12 to 24 inches in diameter, and "large boulders," those stones of more than 2 feet at their greatest length or breadth.

An irregular bottom, such as made up of rubble and boulders, provides shelter for young trout as well as old. Such is not the case in bottoms of fine gravel, hardpan, or sand.

Shade.—The stream should be described as "densely shaded" if overhanging brush or trees shade nearly all the water, "partly shaded" if both open and shaded areas are considerable, and "open" if the shaded area is slight. State the cause of shade, i. e., the size and kind of trees or brush.

Aquatic vegetation.—Note should be made of the types and abundance of water plants which are observed. As mentioned above, this vegetation is of the greatest importance not only in providing food for the organisms upon which the trout live, but also in providing shelter for these organisms and for the young trout. It should be described as to the relative occurrence of higher plants, algae, and mosses. If noticeable upon practically every rock, or margining the stream, it should be indicated as "abundant"; if observed on approximately half of the rocks or patches here and there in the stream, it should be recorded as "common," and if observed but seldom in a stretch of stream, it should be reported as "scarce."

Fish foods.—The most important natural fish foods are those which have a part or all of their life history in the water itself. These include the mayflies, stoneflies, caddisflies, and various forms of two-winged flies (Diptera); also crustaceans, such as fresh-water shrimp, crayfish, and sowbugs, and mollusca in the form of snails and clams, small fishes, and fresh-water annelids. In addition to these primarily aquatic organisms, a considerable source of food is found in terrestrial forms which fall into the streams by accident, such as earthworms, grasshoppers, ants, bees, wasps, beetles, flies, moths, etc. The quantity of this drift food is very difficult to estimate, but it is generally accepted that it is of considerable importance. In general, those streams which are partially shaded by trees and bushes seem to receive the greatest quantity of land forms. Estimates of the bottom fauna of trout streams are to be based upon square-foot samples taken with the apparatus devised by the Bureau, a description of which may be found on p. 35.

Instructions for using the stream-bottom sampler.—The net is grasped by the handle, or directly by the vertical frame, and its lower edge is worked into the bottom with the opening facing upstream. If

spaces still occur beneath this edge they may be dammed up by pushing sand or gravel in front of it. The stones and gravel inside the horizontal square-foot frame are now turned over and stirred up with the hands. If large stones bearing Hydropsyche nets, or the attached cases of Glossosoma larvae, or if cased larvae and pupae of other organisms are present, these stones may be removed from the area and placed in a white enameled tray or pail which may be carried into the field with the sampler, and the organisms picked off later. After thoroughly stirring up the stones and gravel the contents of the net can be transferred directly to a receptacle containing water, from which the animals are removed for counting and weighing.

FIGURE 3.—The stream bottom sampler in use.

In taking bottom samples in swift water containing fine sand and gravel in considerable quantities a pail and sieve may be used to great advantage. The pail is usually filled at least half-full of water before the net with its bulky contents is introduced into it. Many organisms separate themselves from the other content while it settles to the bottom. By a series of decantations, after each of which water from the stream is permitted to flow vigorously over the edge of the pail, a high percentage of the animals present can be removed. Stirring the sand and gravel by hand is likely to destroy the organisms.

In the field or laboratory time and eyestrain in removing preserved organisms from gravel and sand can be saved by manipulating bottled samples as follows: Empty the sample into a white enameled pan and spread the sand and gravel gently over the entire bottom. Play a stream of water over the contents to float organisms to the surface. Decant into a 30-mesh sieve and repeat the process a few times until practically all organisms are removed. After a few decantations the gravel and sand, practically free of bottom animals and debris, can be gone over easily to pick out the few remaining

animals. A reading glass of about 5 inches diameter helps considerably. Whenever possible the animals occurring in bottom samples should be weighed, as numbers alone do not give a complete picture of the food supply. Often samples are collected in which the numbers of animals present are large, but their bulk small. The presence of larger animals such as crayfish, salamanders, fresh-water shrimp, the larger stonefly and mayfly nymphs, and caddis larvae, add materially to the weight of bottom samples, and are highly important as fish food. In counting and weighing, crayfish and salamanders should be included, but omit fish such as sculpins and darters which may swim away quickly while the sampler is being placed in position.

A pocket assay balance, with a capacity of 10 g and sensitive to one-fourth mg, may be used for determining the weight of bottom animals in the field. The volume may be estimated by placing the organisms in a graduated cylinder or centrifuge tube partly filled with water, noting the displacement in cubic centimeters. Studies of the specific gravity of the principal fish-food organisms have shown them to be slightly heavier than water. In determining weight or volume, the following method should be used: Place organisms freshly removed from a vial, watch glass, or other receptacle, on blotting paper of good absorbing quality and allow to drain for 1 minute before transferring to the pan of a sensitive balance, or to a graduated tube. In samples containing large numbers of animals, move them about on the paper without scattering them individually over the blotting paper. In samples containing molluscs and case-bearing caddis worms, either the animals should be removed from their shells or cases before weighing, or a factor applied to compensate for the skewing brought about by uncompensated inclusion of shells and cases.

The following standards of richness of bottom foods are given tentatively to aid in a preliminary classification of streams as to food supply:

Grade 1. Rich; weight or volume greater than 2 g or 2 cc per sq. ft.
Grade 2. Average; weight or volume from 1 to 2 g or 1 to 2 cc per sq. ft.
Grade 3. Poor; weight or volume less than 1 g or 1 cc per sq. ft.

Report results as weight, volume, or number of animals per square foot.

Where the bottom at a station is of widely different types a sample may be taken from each type and these counted and weighed together. This procedure will frequently save time and the results are as accurate as need be. In such cases divide the total number and weight by the number of samples upon which the estimate is based.

Fish.—In this space on the survey blank the kinds and relative abundance at each station should be indicated. The supplementary sheet should be used to give this information in greater detail. Estimates of abundance should be made, based on observations, while following up the stream; also upon the results of angling by members of the party or by fishermen met along the stream. In certain small streams where the water is very clear, and pools are shallow, a rather

accurate count of the fish population can be made by careful observation. However, in most cases it will probably be necessary to rely upon the reports of fishermen and upon the catches made by the party. These estimates should be expressed in terms of the number of each species observed in an expressed length of stream, or in terms of the number of different species caught per hour of fishing. The average size should be given in each instance. Where seine hauls are made, the approximate length of haul should be recorded, together with the number and average size of the catch.

In rapid rocky streams found in the West it has been our experience that seining at night by the light of a gasoline lantern is the most successful method of sampling. Under these conditions the fish appear to be more or less dazed and can be readily captured with a small seine. It is also possible to make a fairly accurate count of the different size of fish by traveling up the stream and using a powerful light. All of these methods should be used to furnish this highly important information as completely as possible.

Collections of fish, particularly minnows and other forage fish, should be made in each principal stream and in the more important tributaries. Representatives of each species, and some miscellaneous collections, should be placed in formalin diluted in the ratio of 1:15 or, especially if the fish are crowded, 1:9 (i. e., 10 cc formalin to 90 cc water, which gives 10 percent formalin). The abdominal cavity of fish longer than 4 inches should be injected with the formalin preservative, or slits made in the abdominal wall, to insure quick penetration. This is especially important in hot weather. After the fish of one collection are well fixed by the formalin they may be wrapped loosely in cheesecloth with a tag showing the date and place collected, or with a noncorrosive metal tag bearing a number corresponding with that on the card. Large specimens should be tagged separately. If any fish show evidence of disease or parasites, others should be secured and the infected or suspected specimens especially saved for study. After about 3 days it is well to renew the preservative with a 5 percent (5 cc formalin to 95 cc water) solution of formalin.

Enemies.—The presence and relative abundance of enemies of fish life such as kingfishers, herons, bitterns, ospreys, pelicans, mink, snakes, turtles, etc., should be noted. It is frequently very difficult to make any accurate estimate of the number of these predators. However, where they are observed as particularly numerous and appear to be doing considerable damage to game fish, a separate report should be made in detail.

Degree fished.—If it is estimated that approximately 75 percent or more of the legal trout in the stream are removed each season by angling, fishing should be reported as "heavy." If approximately 50 percent are caught, the fishing intensity is considered "medium." If 25 percent or less, underscore the word "light." It is recognized that under the present system no accurate records of catches can be secured. However, an estimate by a trained observer is desirable.

Spawning areas.—Trout, smallmouth bass, rock bass, sunfishes, such as *Lepomis auritus* and *Eupomotis gibbosus*, and wall-eyed pike require beds of loose gravel upon which to spawn. The trout species prefer gravel beds supplied with spring or seepage water where their

eggs, in the late fall, winter, and early spring, may be incubated at temperatures generally higher than the average stream temperatures. Smallmouth bass and the sunfishes select the gravel beds along the borders of the quieter pools, or in sheltered nooks in the more rapid sections. Largemouth bass prefer the firm roots of plants growing in the water, but will spawn on gravel, clam shells, sunken sticks, or other solid substrata in the quieter stretches and mud-bottomed lagoons. Bullheads and catfish spawn in holes in banks, or in other situations with shelter overhead. The location and extent of spawning areas should be reported.

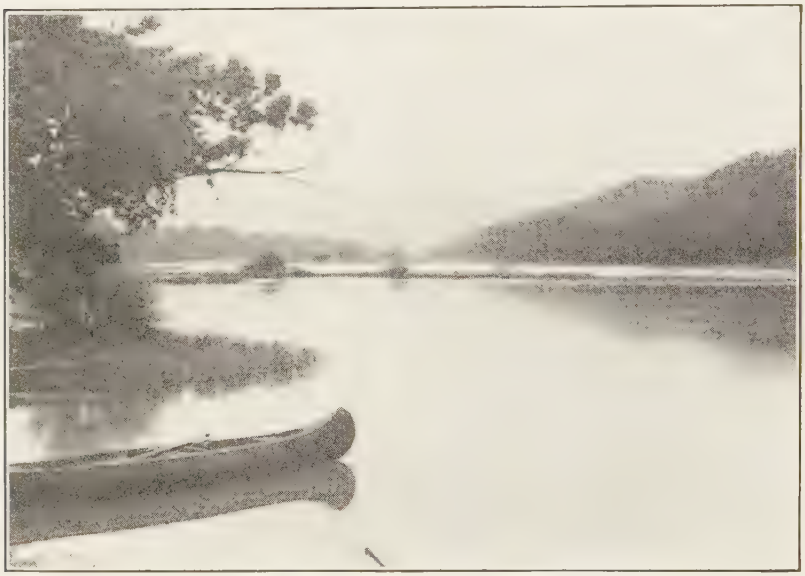

FIGURE 4.—The Shenandoah River, a good smallmouth bass stream.

Fry and fingerlings.—The evidence of successful natural spawning can usually be found in a stream by a trained observer. The fry and young fingerlings of spring-spawning species, such as rainbow and cutthroat trout, appear in the streams from about the latter part of May to the middle of July, depending upon climatic conditions. They will be found in the vicinity of gravel beds, usually close to the banks in the tiny eddies or backwaters, or along the downstream side of partially submerged boulders. The fry in these "pockets" are not very timid and, after the first dash to cover at the approach of the observer, soon reappear at their stations in the stream where they can readily be observed. Larger fingerlings, from 2 to 4 inches in length, usually occupy the small shallow pools, or are found in riffles below the larger rocks. They can be observed best at night by using a brilliant light and wading upstream. The number of fry and fingerlings counted for a certain distance of stream should be recorded. The young of trout can be readily distinguished from those of other fish by their more stocky appearance and the presence of large spots. Do not record trout fry or fingerlings as

seen unless positively identified as such. Indicate by U, M, or L (upper, middle, or lower) the stations where young fish are noted.

Accessibility of stream.—Accessibility of stream by road, horseback, or by travel on foot, should be recorded. If a road follows a stream along the greater part of its course, this fact should be noted. Any roads not shown on the map should be drawn in. The intensity of fishing can almost be predicted if the nature of the roads and the distance from large centers of population are known. If accessible only by trail, give number of miles from nearest road.

Records of stocking during the past 5 years for each of the principal streams should be secured from the State Fish and Game Department, or the Forest Service, by the leader of the party. The principal stocking done during this period should be indicated in this space on the blank. It is frequently the case that the species planted most consistently is not that which is taken most frequently by the fishermen and the survey party. Valuable information as to the adaptability of the various species to certain waters can be obtained by comparison of the planting records and the information as to their relative abundance secured by the survey.

Pollution.—All points along the stream where the effluent from any sewage system, industrial plant, mine, sawmill, or other source of pollution enters, should be indicated on the map by a Ⓟ. The source and type should be listed on the blank, also the apparent extent of its influence. Each case of pollution is a separate problem which requires intensive study by specialists. All that can be done in this survey is to locate the sources and estimate the probable importance of pollution in the watershed being studied. The reports which are made to State Fish and Game Departments will include recommendations as to pollutants appearing to be of importance, and which deserve special attention. Food samples should be taken above and below each point of pollution.

Rearing-pool sites.—Favorable locations for rearing pools should be recorded. While a more detailed investigation of each site by an expert will be necessary before a final decision can be made, it is important that as complete data as possible be provided by the survey.

An essential requirement for trout-rearing pools is a constant supply of pure cold water. This, of course, can best be provided by springs, but in localities where large springs are not available it will be necessary to utilize water from streams. Streams fed by springs or seepage, and which maintain a uniform flow with a comparatively narrow range of temperature, are most suitable for this purpose. The most satisfactory temperatures for trout-rearing pools lie between 50° and 60° F. Where other conditions are favorable temperatures above or below these limits may be tolerated for a time. Streams which are subject to severe floods, or contain much silt and debris after heavy rains, are not suitable for use in connection with rearing pools. Ordinarily, springs which cannot be relied upon to furnish a minimum of 250 gallons per minute at all times should not be considered. Where the water is to be taken from a stream there should be a constant supply of not less than 1,000 gallons per minute since at the higher temperatures usually found

in streams much larger quantities of water are required to keep trout in good condition.

In the case of bass or other warm-water fishes more latitude in the selection of rearing pool sites is admissible. These fish are reared in ponds which only require enough water to maintain a constant level. This water may be taken from either springs or streams. The essential requirements are a large area of fairly level land free of danger from destructive floods, and a soil which will hold water well. In all cases there should be sufficient fall between the source of the water and the ponds so that the latter can be fed by gravity.

FIGURE 5.—A trout stream badly in need of improvement.

The more important data to be recorded on the survey blank are: Character and volume of water supply, temperature, dissolved oxygen and carbon dioxide, alkalinity, topographic suitability for construction of rearing pools, character of soil, difference in elevation between proposed pools and water supply, and accessibility at all seasons. The latter is especially important. Any other pertinent information regarding the site should be recorded. If necessary a supplementary sheet may be used for this purpose.

Fish recommended.—In this space the observer should give his personal opinion as to the species which should be planted, indicating his reasons for these recommendations.

Improvements.—Many streams are notably deficient in certain features which are more or less essential for the support and well-being of fish, while in other respects they provide favorable conditions for a large fish population. For example, a stream with favorable temperatures for trout, and an abundant food supply, may have few pools, a scarcity of gravel beds or other suitable places for fish to spawn, and very little shelter. Such streams will support only a

few trout—and these mostly small—but if suitable pools are provided they become capable of supporting a much larger trout population.

Such deficiencies should be recorded together with the section of the stream and the approximate mileage where such conditions are found. The investigator should also state the general type of improvements needed and the kinds of materials available for such work. The species and size of logs, poles, and brush should be indicated and the character and sizes of rock material such as flat, irregular, or rounded boulders. It is important also to record the accessibility of the area to a stream-improvement crew.

It is not necessary to give detailed specifications regarding the improvements recommended since a careful survey of the stream must be made by an expert on stream improvement before work of this nature can be undertaken.

Remarks.—In this space make any remarks for which no room has been provided on the blank. For example, any reliable information as to the history of fishing in this stream, the amount of protection afforded, and any other facts that might have a bearing on the stocking policy. Posted sections, if any, should be listed in this space.

STOCKING PROGRAM

The following data represents a summary of the factors upon which the stocking plan is based for that section of the stream which is to be stocked.

Average width.—This is determined by the average of the readings in that portion of the stream which is considered worthy of planting. For example, if only the upper 3 miles of the section of the stream covered by the blank is suitable for stocking, it is the average width of this portion which should be recorded in this space.

Stream grade.—This is expressed as described under pools and shelter except that this grade is to be an average of readings in the section to be stocked. This should be expressed by the letters A, B, or C. (A, better than average condition; B, average condition; and C, conditions below average.)

Food grade.—As in the case of the average width, and stream grade, the food grade is to be a summary of conditions in that portion of the stream covered by the blank which is suitable for stocking. If better than average the figure 1 should be used; if average, the figure 2; if below the average, the figure 3.

Section to be stocked.—This section need not necessarily correspond to the section of the stream covered by any particular blank. In fact it may represent mileage on a number of different sections for any particular stream. Also it may happen that different recommendations will be made for different portions of the stream covered by one or more blanks. It is customary to fill in the stocking recommendations only on the blank which covers the lower portion of the stream. For example: If three blanks are filled out for Six Mile Creek, it may be that the lower 4 miles is too warm for trout and too small for bass or other warm-water fish. The next 8 miles might be suitable for brown trout, and the upper 4 miles for cutthroat trout. In this case the stocking program for this stream can be summarized on the blank for the lowermost section. The space for "section to

be stocked," would then read, "4 miles from the mouth (if possible, some prominent landmark should be used to limit the sections), upstream, 8 miles," and on the next line, "12 miles from the mouth, to source, 6 miles." The reason for recommending or not recommending stocking for any portion of the stream should also be clearly indicated. In this case the authority should state "remainder too warm for trout and too small for bass."

Species.—The species recommended should be indicated in this space. In the hypothetical case which we are considering the authority should write in, "Middle section: Brown trout. Upper section: Cutthroat." The question of the most suitable species is often a difficult one to answer. If the maximum water temperatures range above 75° F. it is very likely that neither cutthroat nor eastern brook trout will succeed as well as brown or rainbow trout. If spring-fed areas or spring tributaries are lacking, even though the water be cold enough, cutthroat should be recommended for western streams instead of eastern brook trout. If conditions are suitable for either of these two species the native trout should be given the preference. Every effort should be made to maintain the original species.

Experiments conducted by Professor Embody, at the Cornell University Aquicultural Laboratory, indicate that a water temperature higher than 75° F. is fatal to eastern brook trout. Brown trout died when the temperature rose above 80°, while rainbow trout endured a temperature of 83° F. However, field observations in New York, Michigan, and elsewhere, indicate that in rapid well-aerated streams trout will exist even though the water may reach a somewhat higher temperature for short periods. These extreme temperatures must not be interpreted as the optima, which is undoubtedly considerably below these limits. Observations of the cold streams of Glacier National Park, and elsewhere, indicate that trout will not thrive unless the temperature ranges above 54° F. during the warmer months of summer. The largemouth bass prefers sluggish, mud-bottomed, weedy streams; the smallmouth, rapid rocky rivers. In waters which are too small or too cold (below 80° F. summer temperature), or where their natural food is scarce, bass are stunted in growth and furnish poor fishing. Yellow perch, crappie, bluegill sunfish, and bullheads are natural associates of the largemouth; the red-bellied sunfish (*Lepomis auritus*) and the rock bass thrive in waters with the smallmouth. The pike-perch is found associated with either species of bass in larger rivers where an abundance of forage fish is present. The pike family requires warm, quiet, weedy waters where its natural food supply of small fish is plentiful. The channel catfish (*I. punctatus*) has proven itself well adapted to the warm, continually muddy streams, even where no other game fish exist.

In many instances it may not be advisable to stock game or food fishes although conditions are suitable, for it is obvious that the species will thrive which is already native to the particular stream. For example, an excellent smallmouth bass stream may be found in which small specimens of the species are already abundant and there is insufficient food. In such cases forage minnows will probably be

scarce and it would be more desirable to recommend the planting of minnows or other forage fish. Other streams, perhaps too warm for trout, are found where smallmouth bass, for example, are present, but the stream is so small that it is hardly worth while to recommend stocking any game fish. Such streams might be used by anglers for seining bait minnows, and should be stocked with bait minnows only.

Size.—In waters which are heavily fished, and in which the great majority of adult trout are removed, it is necessary to stock with legal-size trout at various intervals during the season in order to maintain the fishing. This is an expensive practice but it is frequently the only way in which to satisfy the fishermen. Planting with large trout, 5 to 7 inches in length, at less frequent intervals is recommended for larger streams and lakes where a considerable

FIGURE 6.—A trout stream made habitable by a straight log dam.

number of big fish are present. The frequency of such plantings must be governed by the rate of removal. In streams which are less accessible, and consequently less heavily fished, annual stocking with fingerlings, 3 to 4 inches long, is usually sufficient.

Isolated waters which can be reached only by pack train or on foot can be maintained by systematic planting with advanced fry or small fingerlings. The frequency of these plantings will depend on the accessibility of the waters, the success of natural reproduction, and upon the extent to which they are fished. Waters which can be reached easily on foot from some point along the highway, or a recreational center, should receive annual plantings. If overnight pack trips involving the use of saddle horses are required to make the round trip to the lake or stream, biennial plantings should be sufficient. If the water can only be reached by a pack trip of several days, stocking

every 3 years, or even less frequently, may be adequate. Much will depend upon the success of natural reproduction in the more isolated waters in estimating the stocking requirements. If the trout present find conditions suitable for spawning they will probably maintain themselves in the proper numbers if the fishing is light.

Number.—The number of fish to be planted depends upon several factors which cannot be accurately determined in a preliminary survey. The area of the water, the quantity of food, the success of natural reproduction, mortality of various sizes, and intensity of fishing must all be considered. If complete data were available on each water, it would then be possible to estimate more closely the quantity of fish required to produce the maximum yield.

In order to place the stocking of trout streams on a more rational and systematic basis, Dr. Embody, in 1927, published a stocking table giving the number of 3-inch fingerlings to be planted in streams of various types. He pointed out, however, that the numbers recommended were "tentative, and subject to revision as further investigations reveal the true status of the factors concerned." This table has been widely used and has been made the basis of practically all attempts to develop a scientific stocking program.

Dr. Embody's table was developed primarily for the streams of western New York which are subjected to very heavy fishing and in which there is very little natural propagation. Experience indicates that under ordinary conditions it is advisable to reduce the stocking rate somewhat and also make some readjustments in the estimated survival of fingerlings of different sizes. While it is hoped that a revised table will prove more serviceable for general use, it still remains true that the numbers recommended are purely tentative and will doubtless require considerable revision in the light of future investigations.

Even though our knowledge is too limited to make it possible to outline a truly scientific stocking policy at this time, recommendations based on the results of the survey will do much to increase the efficiency of artificial stocking and be a great aid to any program of fish management.

Since there is even less information on which to base a planting table for bass and other warm-water fishes it is believed that definite recommendations for stocking these species would not be justified at the present time. It seems probable, however, that these fish are better able to maintain themselves by natural propagation than trout and consequently the stocking rate should be much less.

Table 1 indicates the number of 3-inch fingerlings to be planted yearly, and per mile, for streams of various widths and showing different combinations of food and pool conditions.

In order to use this table, one must first determine the average width of the stream, the number of miles suitable for stocking, and values for stream conditions (A, B, and C) and food conditions (1, 2, and 3) as already described.

TABLE 1.—*Planting table for trout streams*

Width of stream (feet)	Number of 3-inch fingerlings per mile								
	A-1	A-2	A-3	B-1	B-2	B-3	C-1	C-2	C-3
1	80	65	50	65	50	35	50	35	20
2	160	130	100	130	100	70	100	70	40
3	240	195	150	195	150	105	150	105	60
4	320	260	200	260	200	140	200	140	80
5	400	325	250	325	250	175	250	175	100
6	480	390	300	390	300	210	300	210	120
7	560	455	350	455	350	245	350	245	140
8	640	520	400	520	400	280	400	280	160
9	720	585	450	585	450	315	450	315	180
10	800	650	500	650	500	350	500	350	200
11	880	715	550	715	550	385	550	385	220
12	960	780	600	780	600	420	600	420	240
13	1,040	845	650	845	650	455	650	455	260
14	1,120	910	700	910	700	490	700	490	280
15	1,200	975	750	975	750	525	750	525	300
16	1,280	1,040	800	1,040	800	560	800	560	320
17	1,360	1,105	850	1,105	850	595	850	595	340
18	1,440	1,170	900	1,170	900	630	900	630	360
19	1,520	1,235	950	1,235	950	665	950	665	380
20	1,600	1,300	1,000	1,300	1,000	700	1,000	700	400

Table 1 refers to 3-inch fingerlings only. To determine the required number of 1-, 2-, 4-, 5-, or 6-inch fish, multiply the number given in table 1 by the factor given in table 2.

TABLE 2.—*Factors for determining the required number of fish and the approximate percentage of survival*

Size (inches)	Factor	Survival	Size (inches)	Factor	Survival
		Percent			*Percent*
1	10	5	4	0.7	70
2	2.5	20	5	.62	80
3	1	50	6	.55	90

Table 1 covers streams up to 20 feet in width. Values for wider streams may be determined by multiplying the number given for a stream 1 foot wide by the width of the stream in question.

Calculate the number of fish required of the sizes recommended and record this on the blank. Recommendations as to size should take into account the sizes that are available for distribution at nearby hatcheries at the time the plantings are to be made. This information can usually be obtained from the hatchery superintendents. The sizes of fish available will vary, depending on water temperatures, the strains of fish at various hatcheries, and rearing facilities. Any stocking plan is much more likely to be followed if the number and sizes of fish recommended are available for stocking. When legal-size fish are to be planted it is usually better to plant them at intervals throughout the season, rather than all at one time. In all cases the fish should be distributed more or less uniformly along the stream and not dumped in large numbers at a few easily accessible points.

These recommendations are intended primarily for streams that are fished heavily and in which there is relatively little natural propagation. In the case of streams which are less intensively

fished, and in which there is considerable natural propagation, the numbers given in the table should be reduced 25 to 50 percent, depending on the abundance of native trout of various ages.

FIGURE 7.—Pool formed on a trout stream by a boulder dam.

LAKE AND POND SURVEY

METHOD OF STUDY

The study of a lake or pond is more difficult in many ways than that of a stream since the data cannot be as readily collected and the interpretation is likewise more difficult. Certain stations are to be selected on each lake at which the following data should be collected: Temperature of the air, temperature of the surface, temperature at various depths, as described under "temperatures," color and turbidity, character of the bottom, chemical analysis, depth, and counts of invertebrates from Ekman samples and plankton hauls. These stations should be chosen with care so as to be representative of the lake studied. For example, if soundings in various parts of the lake show that it is relatively shallow over the greater part of its area, one station should be chosen in a typical section having the average depth of water. Larger lakes should be studied by stations at as many points as the character of the lake differs markedly in order that a true picture of representative conditions may be obtained. For example, a lake 5 miles long and 1 mile wide might have approximately half its area in shallow water, and the remainder might be of rather uniform depth, varying from 50 to 60 feet. If no large inflowing streams are present, two stations in the shallow area and two in the deeper portions might be sufficient to indicate the general character of the lake.

In addition to these regular stations observations should be taken at various points along the shores in order to determine the type of bot-

tom, areas of vegetation, relative abundance of shore foods, fish present, etc. It has been the policy of previous surveys to place the first station rather near the outlet of a lake and, if a large tributary stream enters, another station is generally placed several hundred yards from its point of entrance. Since a complete picture of conditions in the lake can not be obtained except through a seasonal study, a preliminary survey can do no more than indicate the general character of a particular body of water.

The data called for on the face of the blank is essentially the same as that for streams. However, in the case of lakes, a careful sketch should be made where indicated, showing the outline of the lake and certain other features as follows: North should be plainly indicated by an arrow placed to the right of the map. The location of stations should be shown by a circle containing the number of the station. Soundings should be reported by X's followed by the depths in feet. A contour line should be drawn as accurately as possible which will indicate what portions are over and under this depth. The locations of the principal weed beds are to be shown by means of cross hatching. The point of entrance of tributary streams should be indicated accurately. If the lake studied is of considerable importance as a fishing resort and has an area greater than 1 square mile, a blank sheet of paper should be used for this sketch and should be enclosed with the regular lake sheet.

Character of watershed.—The proper term or terms should be underlined to indicate the nature of the surrounding country as contrasted with that immediately along the border of the lake. If more than one type is indicated give the percentage of each.

Name of lake.—The name of the lake as given on the map should be used, followed by any other name, in parenthesis, which is commonly applied to this body of water. If no name is given on the map the name commonly used should be given or, if the lake has no unofficial name, the number used on the front of the sheet should be repeated here. Instructions for designating the waters of several systems have already been described and should be followed here. The importance of accurately designating each lake should be obvious.

Altitude.—On U. S. G. S. maps the exact altitude of the more important lakes is usually given. Where this information is not available from the maps, the approximate altitude as determined by contour lines or from the elevation of nearby peaks or benchmarks should be written in, followed by the word "approximate."

Area.—The area of lakes of less than 1 square mile may be determined with sufficient accuracy from a master map, or from a scale map prepared by the plane-table method which is described in detail in the appendix (see p. 37).

If facilities for accurate mapping are not available, or for some reason the expenditure of time for this work does not seem to be justified, it may be possible to determine the approximate length and average width and thus obtain a useful estimate of area; particularly of the area where the depth is 50 feet or less.

Natural or artificial lakes.—The proper designation should be underlined, followed by a note as to the purpose of the lake if it is artificial. For example, whether for power, irrigation, mining, water supply, or recreation, etc.

Height of dam.—Measurements should be made of the height of the dam at the spillway if the lake is of artificial origin. The height of the dam is of considerable importance in restricting the natural movements of fish both above and below it.

Fishway.—The presence of a fishway should be indicated: also notes as to the efficiency of this installation or the need for same.

Character of shore line.—This refers to the immediate margin of the lake and should be indicated by the terms "rocky," "swampy," "wooded," or "meadow." The approximate percentage of each type of shore line should be given here also.

Principal tributary streams.—The tributaries of a lake are of the greatest importance in a survey of this nature, since most of the natural reproduction of trout usually occurs in streams. Successful spawning may be limited or entirely restricted by the size and character of these tributaries. Each tributary having an average width of 3 feet or more, and a flow of 50 gallons a minute or more, should be written up on a separate stream sheet. These sheets should be enclosed with the lake sheet. A note should also be made of smaller tributaries, particularly if these are spring-fed and numerous.

Fluctuation in water level—causes and feet variation.—If the lake is visited but once during the season, it is difficult to determine the maximum fluctuation which occurs during the year. This is particularly true if a study is made during the high-water level. In this case the reports of residents and Forest Service officers must be secured. If a study is made late in the season, at the end of the dry period, it will be possible to estimate the number of feet of fluctuation by observing the high-water marks on rocks, trees, etc. If fluctuation is caused by withdrawals for irrigation or other use, information as to the extent of the fluctuation can be secured from the Forest Service or the company which uses the water. Since the carrying capacity of a lake is determined by its low water level, it is essential that information on reservoirs be reasonably accurate.

To determine the depth, temperature, and oxygen conditions, a representative cross-section near the middle of the lake should be chosen. Soundings should be made at points 100 and 200 feet from shore, and approximately half-way across. Temperature and oxygen determinations are treated in a later paragraph.

Shoal areas.—Productivity in a lake is largely dependent on the number and character of the shoal areas. The extent of the shoals, that is, water having a depth less than 50 feet, should be rather closely determined and indicated by a contour line on the map of the lake which is made by the observer. This zone contains aquatic plants and is the principle forage grounds for fish. The type of bottom in these shoal areas should be determined and expressed in percentage.

Deep areas.—Water over 50 feet in depth will be considered as deep and should be indicated by the 50-foot contour line. The general type of bottom should also be recorded.

Temperatures.—The temperatures of both the air and water should be taken at the inlet and outlet. The hour and weather should be indicated as described under "stream instructions." A series of temperatures should also be taken along the cross section by using a thermometer in the Kemmerer sampler. The bottle must be allowed to come to the temperature of the water each time and for very accurate work a reversing thermometer should be used. In this case allow at

least 2 minutes for each reading, with the exception of the first, which should be given about 4 minutes. These readings should be taken 1 foot below the surface and at 10-foot intervals to the bottom. The thermocline is a zone in which the temperature drops very rapidly, above which there is a gradual rise, and below which there is a gradual fall. Since the majority of plankton organisms develop in the epilimnion—the water above the thermocline—it is important to determine if a thermocline is present, and the approximate thickness of the epilimnion. The temperature sheet should be used to record water temperatures at various levels at the different stations in larger lakes.

Color and turbidity.—Color is expressed by the terms "white," "brown," and "dark brown," as described under "stream studies." Turbidity in lakes will be measured by lowering a Secchi disk, 20 cm in diameter, alongside the boat opposite the sun. The point at which

FIGURE 8.—Making a chemical analysis in the field. Note the portable kit designed especially for field work.

this disk disappears from view should be noted. The disk should then be raised until it reappears and the average of these two readings used to express the turbidity. These readings should be taken at each station on the cross section.

Chemical data.—A separate sheet will be provided for recording chemical data. These data should be secured, along with the other information to be collected, according to instructions in the appendix prepared from "Standard Methods of Water Analysis." Analyses of the surface water near the outlet, and 1 foot from the bottom at one of the deeper stations, should be made. If the oxygen is below 4 parts per million at the deeper station this test should be repeated at two intermediate depths. Dissolved oxygen should be determined in a like manner at all other stations in such a lake.

Higher plants.—The location of the principal stands of aquatic plants should be indicated on the sketch of the lake as previously instructed. In the space provided on this blank under "Emergent" should be given the dominant kinds of water plants which reach the surface, such as pondweeds, waterlilies, water buttercup, etc. Notes should also be made as to the density of these stands which should be recorded as "abundant," "common," or "scarce."

Submerged plants are more difficult to study since they may extend into a considerable depth of water. Frequent sampling with the Ekman dredge will indicate their presence in turbid water or, in the case of clear quiet water, they may be observed quite readily. The type and relative abundance of this vegetation should be noted, using the same terms as used for the emergent type.

Algae—kinds and abundance.—The principal algae, such as Chara, Nitella, and simpler types such as Cladophora, etc., are of greatest importance in providing food and shelter for the organisms which furnish the principal food of fishes. The type and abundance should be indicated, using the same terms as described for the higher plants. If there is any doubt as to the kind of vegetation present, samples should be preserved in a 10 percent solution of formalin and labeled for future identification.

Vertebrates.—It is very important to determine as accurately as possible the species of fish present and their relative abundance. The greater the variety of methods used in this determination, and the more intensive the effort, the more accurate will be the results. The type of gear employed will depend upon local conditions; however, the following have proved most advantageous: Minnow seines 6 20 feet long; seines 150–200 feet long and 12 feet deep, with a 1-inch mesh near the ends and running to ¼-inch mesh in the bag at the center; fyke nets; gill nets of ⅝–4 inch mesh; and trammel nets. Hook-and-line and set-lines should not be ignored, and fishermen's reports are of value.

The average size should be recorded for each species, along with the relative abundance in the haul, and the authority for reports from fishermen. The presence of other vertebrates such as salamanders, frogs, turtles, snakes, and fish-eating birds should also be noted.

Invertebrates.—The Ekman dredge will probably be most suited for the quantitative study of the invertebrate bottom fauna of lakes. In obtaining samples care should be taken to collect a series of samples representative of all types of bottom. The Ekman dredge is not suited for collections in coarse sand, gravel, etc., however, and its use wherever possible should be supplemented with other quantitative devices, such as the Needham metal square foot which can be made to fold up and can be used in shallow water, and the Peterson grab, which will collect in sand and occasionally in gravel. The latter is a very heavy sampler and probably will not be practical to transport except in special studies.

After the sample has been collected, probably in a pail, it should be washed to remove the organisms for weighing. This can be accomplished by taking small portions in a 40-mesh sieve and washing them with a rotary motion in the water of the lake or pond to remove the soil. The sample may then be transferred to a white pan for separating the organisms, or to a bottle for preservation. Where no quantitative device can be used the approximate number per square foot of

bottom should be determined by turning over rocks in several areas at various points along the shore.

The procedure from this point is the same as that described under the technique for handling stream organisms. Numbers and weight should be recorded along with the type of bottom found in the sampler. If the number of organisms in a single dredge sample is insufficient for weighing, four samples may be collected and combined for a square-foot sample. Large pelecypods should be eliminated, and other mollusca and Trichoptera weighed without the shells or cases.

A determination of the weight of macroscopic bottom organisms should be made for a sample collected with an Eckman dredge or a Peterson grab. The sample is collected by lowering the dredge over the side of the boat with jaws expanded until it rests firmly on the bottom. A "messenger" is dropped which trips the release and allows the jaws to close. The dredge should be raised cautiously from the bottom so that the largest sample possible may be collected and it should be pulled to the surface with a steady movement. Care must be exercised that the dredge does not move up and down through the water during this process lest some of the organisms be lost. As it approaches the surface a receptacle should be at hand so that the dredge can be rapidly lifted from the water into the container for the sample. In doing so the dredge should not be raised entirely out of the water. If it is allowed to drain before reaching the receptacle the water gushes out around the jaws washing the surface film of the bottom sample with it, as well as a number of organisms.

Plankton.—The use of plankton as an indication of the fertility of a lake is subject to a number of limitations. The quantity fluctuates with the season due to cycles of the various organisms. Because of this it is necessary to sample throughout the year if an adequate picture is to be acquired. Samples taken consecutively vary due to the presence of swarms and because of prevailing winds at the time the samples are taken.

In general, however, if there is an abundance of plankton, one may associate it with an abundant bottom fauna; while a scarcity of plankton is found in lakes with a small bottom fauna. Therefore, it indicates in a general way the conditions in the lake, but may or may not indicate the productivity. For this reason it is believed that some method of comparing samples taken according to a standard plan of collection would be of more value than a more intensive survey of the plankton fauna in various lakes investigated.

The sample should be collected quantitatively by some method such as dipping in a 12-quart pail with a mark to indicate the 10-liter measure. Fifty liters of water should be strained by pouring through a 20-mesh silk bolting cloth net suspended in the water. The most convenient type of net is that used by Birge and Juday. This is described on page 75 in "Microscopy of Drinking Water" by Whipple.

After the sample has been collected the sides of the net should be washed down by splashing water against them to get all of the plankton into the bucket. Detach the bucket, place a centrifuge tube under it and drain the water out with a slight rotary motion. Rinse the bucket by permitting the water to come into it through the sides. Again drain the remaining water out of it into the centrifuge tube.

Add ½ cc of formalin to each 10 cc of plankton and water. Place a label in the tube, giving the date, the name of the lake, station number, collector's name, etc. Allow each plankton sample to settle for approximately 24 hours and then read the volume to the nearest 0.1 cc and record on the field blank. A comparison of the volumes from different lakes gives some idea of their relative richness.

In lakes of less than 1 square mile in area, one cross section should be taken. This should consist of three stations; two samples should be taken some distance from shore and one in the middle. Larger lakes, or those of irregular shape, may require additional cross sections. These should be taken in such a manner as to give the best possible picture of the body of water.

Care of the plankton net.—Care must be taken to keep the plankton net in a condition of maximum efficiency. Any holes may be repaired by tying them off with thread on the outside.

Before collecting plankton at each station, detach the bucket and carefully wash the net by reversing and drawing it through the water. Similarly wash the bucket by drawing it through the water backwards. After the sample has been taken the net should again be washed. Each night the net and bucket should be washed and dried thoroughly.

Spawning areas.—As has been previously mentioned under tributary streams, successful spawning of trout, other than mackinaw trout, appears to be largely limited to suitable areas in the inflowing and outflowing streams. However, a few instances are on record where cutthroat trout have maintained themselves in lakes having neither inlets nor outlets, and it is known that eastern brook trout will spawn in lakes over suitable gravel beds through which spring water seeps. Possibly this applies to other species in some degree. The mackinaw, or lake trout, scatters its eggs over gravel bars and rocky reefs in fairly deep water. Smallmouth bass require gravel shoals for spawning. Largemouth bass usually spawn in nests constructed on the roots of aquatic vegetation and occasionally over graveled areas. The bluegill sunfish, or bream, and the crappie apparently have requirements similar to those of the largemouth black bass. The yellow perch scatters its egg strings over submerged water plants or sunken brush. The common bullhead utilizes holes in muddy banks as nesting areas. Pike-perch usually run up streams to spawn, but they are also known to spawn along the shores of lakes in shallows 3 to 10 feet in depth. The eggs are deposited on sand and gravel free from sediment. Pickerel and northern pike deposit their eggs in marshy places among water plants, submerged branches, etc., and occasionally on gravel or among rocks.

Young fish.—The species and relative abundance of young fish along the shores should be recorded here, using the same terms as described for records of larger individuals.

Accessibility.—Indicate whether the lake is accessible by road, by horseback, or by foot trail. If by foot trail, give the approximate mileage from the nearest road.

Boats available.—The number and character of boats available should be indicated in this space. Also the number of rafts found on the lake. The latter is a valuable indication as to the popularity of certain of the less-accessible lakes.

Pollution.—This should be described according to stream study instructions.

Degree fished.—

Rearing-pool sites.—

Fish recommended.—

Remarks.—

These spaces should be filled in as indicated for stream study.

CLASSIFICATION OF LAKES

Although environmental conditions in lakes have been studied intensively in this country no serious attempt has been made to classify them. One reason for this is probably the fact that relatively few quantitative studies have been made of the bottom fauna of lakes. Our information regarding the species of bottom organisms present is also far from complete. European lakes have been studied far more intensively and as a result have been divided into three major groups, the oligotrophic, eutropic, and dystrophic types. One of the fundamental distinctions between these three types of lakes is the relative amount of available nutritive materials present. On the one extreme are the typical oligotrophic lakes with clear water, rich in oxygen, and deficient in nutritive materials. The other extreme is represented by the dystrophic lakes with water stained brown by humic material, poor in oxygen, and rich in organic matter. The entrophic lakes occupy an intermediate position between these two extremes.

The extent to which this classification is applicable to American lakes is still undetermined. There is no difficulty in finding lakes that show the typical characteristics of each type, but there are many that do not fall readily into either of the three groups as at present defined. While these border-line cases are difficult to classify, it is believed that the classification proposed by Thienemann and Naumann will be helpful in evaluating lakes for purposes of fish management. This classification, with some modification, is given below. It should be pointed out that the classification applies to all lakes, and not merely to trout lakes, a provisional classification of which is given under "Stocking program."

Oligotrophic lakes.—Are deep lakes with narrow shoals, or none; with a volume of hypolimnion greater than epilimnion; color of water blue to green; transparency high; poor in nitrogen and phosphorus; humic materials absent; calcium content variable; minimal quantities of suspended detritus; bottom deposits poor in organic materials, and these relatively stable (not putrescent); oxygen content relatively uniform from surface to bottom, deep water usually containing 60–70 percent of saturation; poor in plankton, and with few littoral plants; green algae and sometimes diatoms predominate over the blue-green algae; bottom fauna relatively rich in numbers and in species that require a high oxygen content, such as *Tanytarsus;* probably about 30–100 animals per square foot (0.25–1.00 g wet weight per sq. ft.); deep-dwelling salmonoid fishes present.

Eutrophic lakes.—Usually shallow with broad shoals; volume of hypolimnion smaller than epilimnion; color of water green to yellow and brownish green; transparency low; rich in nitrogen and phosphorus with only a small amount of humic materials; calcium abundant, seldom scanty; large quantities of suspended detritus; rich in putrescent organic materials produced in the same basin; little or no

oxygen in hypolimnion; oxygen content seldom above 40 percent of saturation; putrescent bottom deposits; littoral plants abundant; plankton rich; water bloom abundant, the blue-green algae, diatoms *Peridiniaceae* and *Chrysomonadales* predominating over the green algae; bottom fauna poor in species but rich in numbers of organisms tolerant of variable oxygen contents; species of *Chironomus*, *Corethra*, and *Oligochaeta* almost always present; probably 100–1,000 animals or more per square foot (1.0–3.0 g or more).

Dystrophic lakes.—Are deep to shallow in bog surroundings or in geologically old land areas; color of water yellow to brown; transparency low; poor in nitrogen and phosphorus, calcium scanty; rich in humic materials; rich in deposits largely derived from sources outside the lake, little or no oxygen in hypolimnion, seldom above 40 percent; few littoral plants; phytoplankton scanty; water bloom very rare; bottom fauna poor both in numbers and species, probably less than 30 animals per square foot, sometimes none; deep-dwelling salmonoid fishes always absent.

Stocking program.—As previously stated, it is impossible to set up definite standards for classifying lakes according to the amount of fish food present. After completing the survey of a lake the investigator must decide to which of the three categories of relative richness the lake should be allocated. This decision can be made more readily and accurately if the investigator has in mind for comparison lakes which clearly belong to each of the three grades of richness.

Table 3 indicates the number of 3-inch trout to be planted per acre of water surface in lakes of the three grades of richness and of various combinations of fishing intensity and spawning effectiveness. In estimating the acreage to be planted only water 50 feet or less in depth should be considered. This will include the entire area of shallow lakes, while in deep lakes it may happen that a considerable percentage of the total area will not be included in the estimated acreage for stocking purposes.

TABLE 3.—*Planting table for trout lakes; number of 3-inch trout per acre*

Fishing intensity	Grade I—Food abundant		Grade II—Food average		Grade III—Food poor	
	Good spawning	Poor spawning	Good spawning	Poor spawning	Good spawning	Poor spawning
Heavy	180	240	90	120	50	60
Medium	90	180	45	90	25	45
Light	30	120	15	60	10	30

Table 3 refers to 3-inch fingerlings only. To determine the required number of 1-, 2-, 4-, 5-, or 6-inch fish, multiply the number given in table 3 by the factor given in table 4.

TABLE 4.—*Factors for determining the required number of fish and the approximate percentage of survival*

Size (inches)	Factor	Survival	Size (inches)	Factor	Survival
		Percent			*Percent*
1	10	5	4	0.7	70
2	2.5	20	5	.62	80
3	1	50	6	.55	90

APPENDIX

SYMBOLS AND ABBREVIATIONS SUGGESTED FOR USE ON FIELD SURVEY BLANKS

Weed bed areas in lakes or ponds

Survey stations in lakes or ponds ① ②

Survey stations in streams ⊗

Pollution effluent Ⓟ

Spring ⊙

Dry stream beds, or streams becoming dry - - - -

Diversions

Dam

Lake or pond inlet

Lake or pond outlet

Cubic feet per second	C. F. S.
Gallons per minute	G. P. M.
United States Bureau of Fisheries	U. S. B. F.
United States Forest Service	U. S. F. S.
United States Geological Survey	U. S. G. S.

CONVERSION TABLES

1 pound avoirdupois equals	453.592 grams. 7000.0 grains. 0.45359 kilograms.
1 ounce avoirdupois equals	28.3495 grams. 0.0625 avoirdupois pound. 437.5 grains.
1 U. S. fluid ounce equals	29.573 cubic centimeters. 1.80469 cubic inches. 0.0295729 liters.
1 liter equals	1000 cubic centimeters. 64.0250 cubic inches. 1.05671 liquid quarts.
1 U. S. liquid quart equals	946.33 cubic centimeters. 0.94633 liters. 57.75 cubic inches. 32 fluid ounces.
1 gallon equals	231 cubic inches. 128 fluid ounces. 3.785332 liters. 3,785.332 cubic centimeters.
1 meter equals	39.37 inches. 100 centimeters.
1 acre equals	43,560 square feet. 4,840 square yards. 160 square rods.
1 inch equals	2.54 centimeters. 0.0254 meter.

1 cubic foot per second equals { 60 cubic feet per minute. / 448.83 U. S. gallons per minute.

1 cubic foot equals 7.48 gallons.

One acre-foot of water is an area of 1 acre covered to a depth of 1 foot. One acre-foot of stored water will give a flow of 20 miner's inches of water for 24 hours.

1 cubic foot per second (C. F. S.) = 40 California miner's inches.
1 cubic foot per second (C. F. S.) = 450 gallons per minute (G. P. M.).
1 cubic foot per minute = 7. 48 gallons per minute (G. P. M.).

METHODS FOR MAKING CHEMICAL ANALYSES

Collection of samples.—Bottles for dissolved oxygen samples should be of 250–300 cc capacity and have ground-glass stoppers. A standard short form (33 x 200 mm) model 100 cc nessler tube should be used for carbon dioxide determination. Water samples for the determination of alkalinity may be measured with a 100 cc pipette or volumetric flask into a 250 cc Erlenmeyer flask for titration.

In streams, surface samples for dissolved oxygen may be collected by tilting the bottle to a horizontal position and allowing the water to flow into it very slowly and gently. Care should be exercised to prevent undue aeration and the bottle should be filled so that water is displaced when the stopper is inserted and no air bubbles are left under it. Air bubbles may be averted to a great extent by first rinsing out the bottle to moisten the interior surface.

The carbon dioxide sample may be collected in a similar manner in a low form nessler tube. The water level should be accurately adjusted to the mark by gently pouring off the surplus without undue agitation. This method of collecting samples is suitable for waters which are not heavily saturated or badly polluted, and where a high degree of accuracy is not required.

Samples from various depths may best be collected in a standard 1½-liter Kemmerer sampler. A rubber tube connected to the drain valve at the bottom of the sampler may be used to empty the sample into suitable containers such as the above. The tube is inserted in the bottom of the vessel and the water allowed to flow until the contents of the vessel have been changed twice.

Since no exchange of gases ordinarily affects the alkalinity of the water, it is not necessary to exercise as great care in the collection of the samples such as is required for dissolved gases. All procedures should be carried out according to "Standard Methods of Water Analysis," seventh edition. Much of the following is quoted from that source, with certain modifications.

Dissolved oxygen.—1. To the sample collected in the 250–300 cc ground-glass stoppered bottle, add 1 cc of manganous sulfate and 3 cc of alkaline potassium iodide beneath the surface of the liquid.

2. Replace the stopper, at the same time preventing the entrapping of air bubbles. Shake vigorously for 15 seconds and allow the precipitate to settle until it is contained in the bottom half of the bottle. If this does not occur quite rapidly the shaking should be repeated.

3. When the precipitate has settled add 2 cc of concentrated sulphuric acid above the water level, holding tip of pipette against the

neck of the bottle. Replace the stopper with precautions against trapping air bubbles and shake the bottle vigorously to mix the contents. Up to this point the procedure must be carried out in the field. The final titration should be made as soon as possible thereafter, but an elapse of a few hours is permissible.

4. Transfer 200 cc of the treated sample, measured with a 200 ml volumetric flask, into a 500 cc Erlenmeyer flask. This is conveniently accomplished by carrying into the field a 200 cc flask cut off a few millimeters above the mark and inserted into a pierced stopper which fits the neck of the larger flask. By inserting the mouth of the smaller flask into the larger flask and reversing the two with a slight rotary motion the sample will transfer rapidly.

5. Titrate the sample with 0.025 N. sodium thiosulfate. One or two cc of starch solution should be added only when the color has become a faint yellow after the addition of thiosulfate. Titrate over a white background until the blue color disappears.

Dissolved oxygen is reported in parts per million by weight. If a 200 cc sample is used the dissolved oxygen in parts per million is equal to the number of cc of 0.025 N. thiosulfate required. No corrections are necessary for the reagents added except in work of unusual precision.

Since a 0.025 N. solution of thiosulfate is unstable, this solution should be restandardized or replaced occasionally. Starch solutions, even if preservatives such as chloroform or zinc chloride are added, deteriorate quite rapidly, especially in warm weather. A satisfactory method is to use sterilized solutions in small bottles which are opened as required.

Carbon dioxide.—Collect 100 cc of the sample in a low form nessler tube (200 x 32 mm) according to one of the two methods outlined. Add 10 drops of phenolphthalein and titrate rapidly with N/44 sodium hydroxide until a faint but permanent pink is produced (3 minutes). The sample may be mixed by swinging the container with a circular motion or by rotating it with a circular motion of the wrist. Any agitation of the surface of the liquid tends to change the gaseous content and should therefore be avoided. The free carbon dioxide is equal to 10 times the number of cubic centimeters of N/44 sodium hydroxide used.

Since N 44 hydroxide, or stronger solutions, deteriorate once the bottle is opened, this solution should be restandardized, or a fresh one obtained at frequent intervals. It is convenient to have this reagent supplied in small, tightly corked containers.

Alkalinity.—The alkalinity of natural waters represents its content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates. It is determined by titration with a standard solution of strong acid to certain datum points or hydrogen-ion concentrations. Indicators are selected which show definite color changes at these points.

Since dilute bicarbonate solutions have a hydrogen-ion concentration of about pH 8.0 and dilute carbonic acid solutions a hydrogen-ion concentration of about pH 4.0, these are chosen as datum points, and indicators should be selected which show definite color changes at about these two points. The amount of standard acid required to bring the water to the first point measures the hydroxides plus one-

half the normal carbonates (phenolphthalein) and the amount to bring it to the second point corresponds to the total alkalinity (methyl orange).

The sample may be collected by any method since there is no great danger of changing the alkalinity. Both end points may be determined on the same sample by using phenolphthalein first and continuing with methyl orange after the first end point has been determined.

1. Phenolphthalein alkalinity. Add 4 drops of phenolphthalein indicator to 50 or 100 ml of sample in a white porcelain casserole, or an Erlenmeyer flask, over a white surface. If the solution becomes colored, hydroxide or normal carbonate is present. Add 0.02N sulfuric acid from a burette until the coloration disappears.

The phenolphthalein alkalinity in parts per million of calcium carbonate is equal to the number of milliliters of 0.02N acid multiplied by 20 if 50 ml of sample was used, or by 10 if 100 ml was used.

2. Methyl orange alkalinity. Add 2 drops of methyl orange indicator to 50 or 100 ml of the sample, or to the solution to which phenolphthalein has been added, in a white porcelain casserole, or an Erlenmeyer flask, over a white surface. If the solution becomes yellow, hydroxide, normal carbonate, or bicarbonate is present. Add 0.02N sulphuric acid until the faintest pink coloration appears, that is, until the color of the solution is no longer pure yellow.

The methyl orange alkalinity in parts per million of calcium carbonate is equal to the total number of milliliters 0.02N sulfuric acid used multiplied by 20 if 50 ml of sample was used, or by 10 if 100 ml was used.

Hydrogen-ion concentration.—The pH, or hydrogen-ion concentration, is a measure of the degree of acidity or alkalinity of a solution. It is most accurately measured by means of a potentiometer. For field use a standard colorometric set such as the La Motte block type, or Hellige pocket comparator are suitable. Color disks, or series of ampules covering a definite pH range, are employed and it is best to determine the pH of a sample at or about the middle of the range of a particular indicator. The indicators most often used include bromthymol blue, phenol red, and thymol blue.

The following indicators with their pH ranges are given:

Indicator	*pH range*
Brom cresol purple	5.2–6.8
Brom thymol blue	6.0–7.6
Phenol red	6.8–8.8
Cresol red	7.2–8.8
Thymol blue	8.0–9.6

Care should be taken not to contaminate the sample by inverting the tube against the finger tip to mix indicator and sample. A rotary movement with the wrist will suffice.

DESCRIPTION OF STREAM-BOTTOM SAMPLER

This bottom sampler consists of two brass frames 1 foot square hinged together (see fig. 1), one of which is provided with a net while the other merely overlies the area of riffle to be sampled. The frame of the sampler is constructed entirely of brass as follows: Two pieces ⅛ x ½ x 37 inches are bent to form the three sides of the square frame (fig. 1, *A*) which overlies the square foot of the

stream bottom and (fig. 1, *B*) the frame to which the net is attached, and which is held at right angles to the stream bed. Frame *A* is hinged to a third piece *C* which is made of slightly wider material $\frac{1}{8}$ x $\frac{3}{4}$ x 14 inches. *B* is soldered to this 14-inch piece *C* which is bent in 1 inch on both ends at right angles and set inside of *B* to complete a square 12 x 12 inches. Two brass screws $\frac{3}{16}$ x $\frac{1}{4}$ inch hold *B* and *A* together and provide the hinges. These screws are set rigidly in piece *A* (the free end of piece *A* being outside the ears of *C*), but allows piece *A* to swing freely on them. Two braces are provided (fig. 1, *D*) which gives the frame rigidity when it is opened.

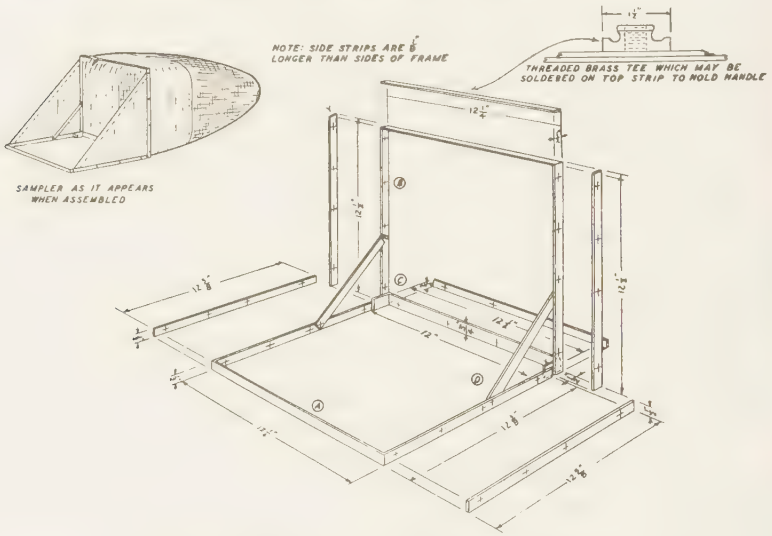
NOTE: SIDE STRIPS ARE 6" LONGER THAN SIDES OF FRAME
THREADED BRASS TEE WHICH MAY BE SOLDERED ON TOP STRIP TO HOLD HANDLE
SAMPLER AS IT APPEARS WHEN ASSEMBLED

FIGURE 9.—Metal frame for stream-bottom sampler.

These braces also keep the net wings from buckling in the face of the current. Pieces *D* are $\frac{3}{32}$ x $\frac{1}{2}$ x 6 inch brass. The ends of the braces are attached to piece *A* by $\frac{3}{16}$ x $\frac{3}{8}$ inch brass screws. The upper ends are notched to fit over $\frac{3}{16}$ x $\frac{3}{8}$ inch screws set in frame *B* at the proper points. A handle for holding the frame in place in the stream bed was made by soldering one-half of a $\frac{1}{4}$-inch T to the center of the $\frac{3}{32}$ x $\frac{1}{2}$ x 12 inch piece that clamps the net to the top of frame *B*. The handle is screwed into the T. A number of different types of handles have been used in the sampler, although the sampler has in most cases been used without a handle. The original handle supplied was in two pieces of $\frac{3}{4}$ x 12 inch brass pipe joined by a $\frac{3}{4}$-inch coupling. Another one-piece handle was made by inserting a short piece of $\frac{3}{4}$-inch brass pipe, threaded on one end, into a 5-inch length of broom handle. The net and wings are attached to the frame by six $\frac{3}{32}$ x $\frac{1}{2}$ x 12 inch brass pieces which overlie the material and are attached to the frame with $\frac{1}{8}$ x $\frac{1}{4}$ inch round-headed brass screws or $\frac{8}{32}$ x $\frac{3}{8}$ inch round-headed machine bolts with hexagonal nuts. Net replacements can be made by removing these plates.

The net is cut 27 inches deep and made of 23-mesh to the inch No. 000 XXX extra double heavy silk bolting cloth. The size, thickness, and quality of the mesh in this material is more important than it may seem. For example, 19-mesh to the inch material will permit the important caddis larvae of *Hydropsyche* to escape. The 23-mesh is probably as small as is practical to use because of clogging, unless it is desired to take the larvae of the midge flies into consideration. Some are captured in the 23-mesh, but it is believed that many are lost. However, the bulk of these small larvae in the average riffle is so small that it is believed unnecessary to consider them, particularly because only a small percent can be induced to leave their tiny cases on the stones. These organisms, it is realized, are very important as food for young fish, but it is the larger fish, 3 to 5 inches, that are usually planted, and these obtain organisms of greater bulk.

The shape of the pattern of the net is shown roughly in figure 1. Canvas is used in about the first 11½ inches of its length and in the wings to increase its durability. The net, if of bolting silk alone, is joined by a five-sixteenth-inch French seam. The bag is hemmed with a double fold three-fourths inch. Extra strength is needed because it underlies the brass plates which hold the net in place. The top of the bag is cut on the fold of the material. A double fold of three-fourths inch is used in the wings for the hem if the wings are made of silk bolting cloth instead of canvas. The greatest length of the wings, 17 inches, is the diagonal, or the side opposite the right angle. The 12¼-inch side is placed on frame A, while the 12-inch side adjoins frame B. All borders, when made of silk, have a ¾-inch seam. The net and tray for sorting animals may be carried in a simple knapsack of canvas.

METHOD OF DETERMINING AREA OF LAKE

Directions for mapping.—Two points, A and B, as widely separated as is convenient, 100 to 300 yds., near the lakeshore, and from which most of the lake can be seen, are chosen. The straight-line distance between these points is measured by means of the steel-thread tape with which the party is provided.

The plane table is now set up over one end of the baseline with the tripod legs spread well apart and firmly planted in the ground and the table approximately waist high. The table is carefully leveled and oriented with the attached compass needle so that one side conforms to magnetic north. This procedure is to be followed each time the table is set up.

A convenient point on the paper fastened to the table is marked to represent the point over which the table is set and is labeled point A. Using point A as a center sight with the alidade to the other end of the baseline and, with a sharp 6 H pencil, draw a fine line toward point B. With the known distance between points A and B determine a suitable scale, preferably one listed at the end of this section, and mark off on the AB line the distance, according to scale, between A and B. Label the second point B.

From point A sight around the shoreline of the lake from left to right bringing the alidade to bear on each major point and draw a line from A toward each point. Label these lines 1, 2, 3, etc., in

order, and record to what each number refers. Example: No. 1, dead tree on point; No. 2, large rock on shore, etc. Complete the circuit of the lake in this manner and then move the plane table to point B. Reorient the table at point B and check by taking a backsight from point B to point A making sure that the line between A and B corresponds to the edge of the alidade when point A is viewed from B.

From point B sight around the lake as before to the various objects which were viewed from point A, draw a line toward each from point B and number each line to correspond with the lines from point A. The point at which the lines intersect, when extended, is the location of the points desired.

If the lake is small and the shoreline entirely visible from the two points, two stations will be enough. If part of the lake is obscured it will be necessary to proceed to some point already located by the intersection of two lines and orient the plane table to correspond, and then set up a baseline and map the part of the lake not visible from the other station.

After all of the various points have been located by intersection, the details of the shoreline between the points may be filled in by careful free-hand sketching.

The soundings are located on this map as they are made and the location and depth of each is recorded.

Determination of area.—To determine the area of a mapped lake, lay over the completed map a semitransparent sheet of coordinate paper ruled in 1-inch squares. Count the number of whole squares within the limits of the lake and carefully estimate the inner area of the squares cut by the shore line of the lake. Add the two together and record as square inches of lake area.

The following data give the number of acres per square inch of map area for the various scales used:

Scale (ft. per in.)	*Acres per sq. in.*
50	0.057
100	.230
150	.52
200	.92
250	1.43
300	2.07
350	2.81
400	3.67
450	4.65
500	5.74

INSTRUCTIONS FOR COLLECTING FISH SCALES

Method of collecting.—The best place to take scales from fish is from the midregion of the body immediately above the lateral line. They may be easily removed by scraping against the outer free tips of the scales with a dull knife or scalpel. Scales should not be taken from the lateral line. With large fish over 12 inches long, it is well to wipe mucus off the side of the fish with a cloth before the scales are scraped loose. Large amounts of mucus make it difficult later to clean the scales for mounting. The scales should then be placed either in regular U. S. B. F. scale envelopes, which are provided

for this purpose, or they can be placed in scale-collection books where the edge has been cut and on which the scales are placed and the edge folded back against the other half of the sheet. The mucus secured with the scale samples is usually ample to attach them firmly in place. Extreme care should be taken to prevent the mixing of scales from different fish. The knife should be wiped clean after each sample is taken. Complete data as to date, name of water, species of fish, sex, total and standard lengths, etc., should be recorded with each sample taken. Where condition factors are also to be determined from the same fish, it is highly desirable that the fish be weighed fresh as preservation in formaldehyde changes the weights markedly.

Scale studies.—For study in connection with rates of growth in fish-population studies it is important that scales be collected from at least a portion of the samples of fish taken by seine hauls, gill-net catches, or other means. Effort should always be made to secure a good number of scale samples, particularly from "problem" types of waters; water that anglers are frequently heard to complain about, and in which fishing, for one reason or another, has greatly declined. Many lakes are known to contain standing populations of stunted, immature fish, due to excessive numbers in relation to food supplies. When such conditions exist, scale studies offer an important means of determining the true conditions, and the stocking policy may be modified accordingly. Frequently waters will be found in which fish are so abundant that they do not achieve normal growth, or legal size, and, in the past, the policy has generally been to stock more fish as a remedy. This is, quite obviously, not the remedy, and it usually makes conditions worse instead of better.

From periodic age determinations of fish from any given lake, over a period of years, it should be possible to note changes in the rate of growth and, therefore, to modify the stocking policy accordingly. If growth falls off, fish may be too abundant and hatchery plantings should be stopped, or fishing intensity increased, to reduce overpopulation. On the other hand, if growth increases, it might be shown to be advisable to plant more fish. Scale studies may prove to be a major means of keeping a check on the growth status of any standing population and serve as a major aid in holding it at its highest level consistent with normal growth in relation to the food supply. Aside from the accumulation of knowledge of growth rate of any given species in any given water, such data can be used to estimate the time required to grow planted hatchery trout to legal size.

Obviously, scales collected cannot be studied in the field owing to the time involved, but should be retained for later study in connection with the write-up of the survey findings. Scale reading requires special training and technique, and untrained persons should not attempt to read them.

CONDITION FACTOR

The condition factor (length-weight relationship) is frequently used as a means of expressing the relative plumpness of fish. To

determine the condition factor, either of the following formulae may be used:

$$\frac{\text{Weight in pounds} \times 100{,}000}{(\text{Standard length in inches})^3} = F, \text{ or}$$

$$\frac{\text{Weight in grams} \times 100}{(\text{Standard length in centimeters})^3} = F.$$

Length of fishes usually recorded:

Standard length.—The distance from the tip of the snout to the end of the last vertebra or base of the caudal fin rays.

Total length.—The distance from the tip of the snout to the center of the fork of the tail.

Always specify which measurement is used.

SIMPLE METHODS FOR MEASURING FLOW OF WATER[2]

By A. L. Anderson
United States Forest Service

In measuring the flow of springs or streams, it should be remembered that the flow will vary considerably during the different seasons of the year and also from year to year. Where water supply improvements are to be constructed, it should be determined that the supply will always be adequate for the satisfactory functioning of such improvements. Therefore, before constructing a water system of any sort, it is desirable to obtain a series of measurements for as many years as possible. Where it is necessary to construct on the basis of one or two measurements, the opinions of local residents will often be of value in determining the probability of the flow diminishing below that at the time of measurement.

Small springs.—The simplest method of measuring the flow of small springs is to place a pipe or trough in the spring and run the water into a can or other container the capacity of which is known. The capacity of the container in gallons, divided by the time required to fill it in minutes, will give the flow in gallons per minute.

Use of weirs.—Where the stream is too large to divert into a container, the best means of measurement is with weirs, which are commonly of three types: (*a*), 90° triangular, or V-notch; (*b*), rectangular; and (*c*), cippoletti type, which is a trapezoidal weir with the sides sloping away from the crest on a ¼ to 1 slope. The triangular weir is suitable for the measurement of small streams whose flow does not exceed 1,000 gallons per minute. The rectangular and cippoletti weirs are suitable for larger streams. Weirs for the measurement of water should be sharp-crested. If they are constructed of wood the edges should be beveled on the downstream side. Weirs constructed of sheet metal give an ideal crest. They should be so placed in the stream that a pool of water will be formed on the upstream side which will reduce the velocity of approach to a relatively small amount. The weir itself should be so installed that there will be no appreciable amount of seepage around or under it, as the only water measured is that which flows over the crest. The "head," or the height of water above the crest, should be measured at a distance upstream from the weir of about three times such head. However, for obtaining the approximate flow it will be easier, and sufficiently accurate, to measure the head directly at the weir notch. This will give a value slightly lower than the true head, which error is on the side of safety. Figures 2 and 3 show the amounts of water that will flow over the triangular, rectangular,

[2] From The Progressive Fish Culturist, No. 26, pp. 6–9.

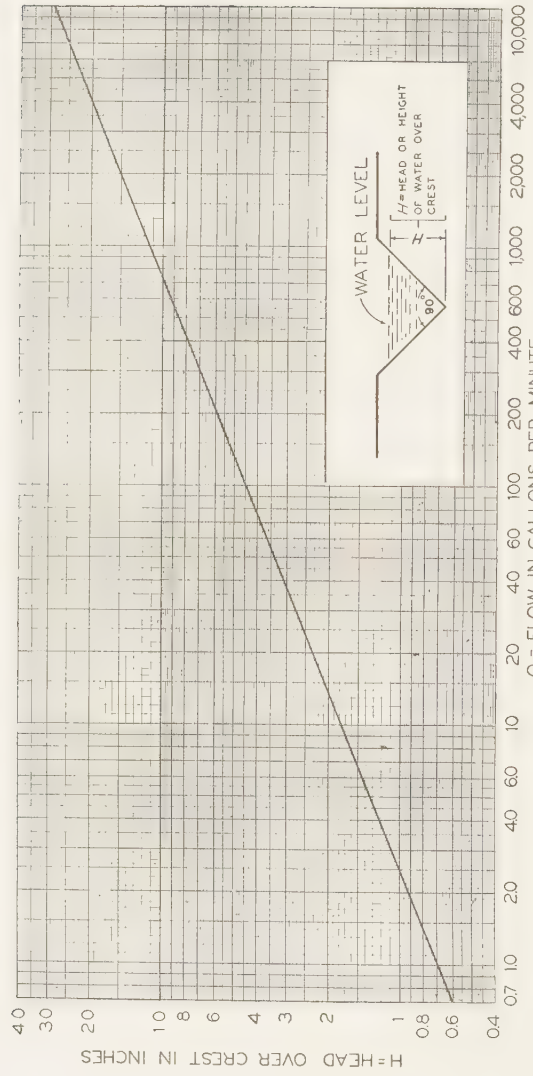

FIGURE 10.—Flow of water over a sharp-edged 90° triangulation weir.
(Based on formula $Q = 2.52H^{2.47}$)

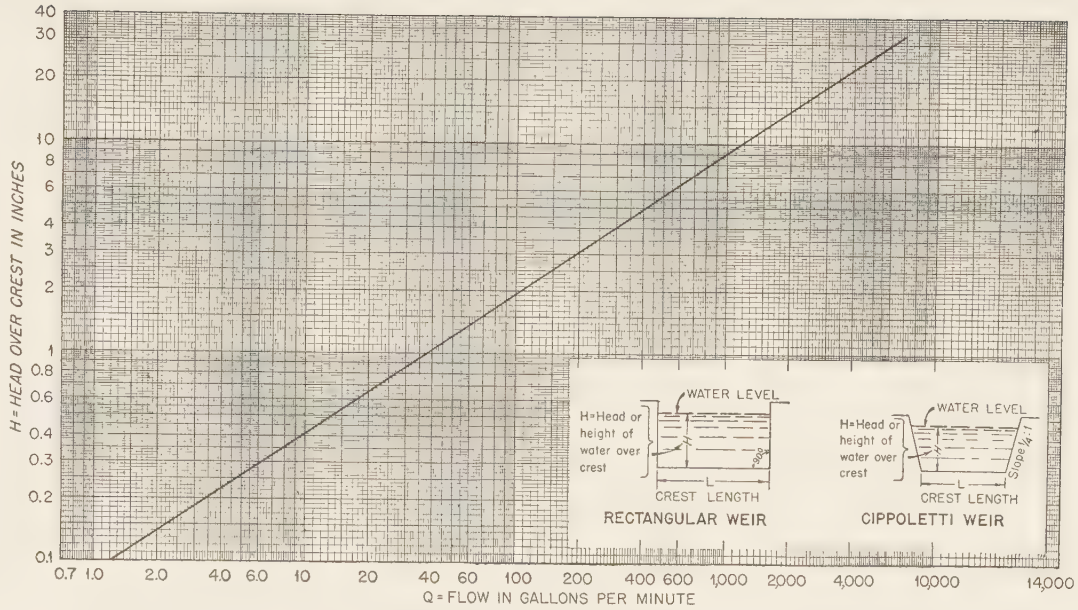

FIGURE 11.—Flow of water over a sharp-edged cippoletti weir having a crest length of one foot.

(Based on formula $Q = 3.367LH^{1.5}$)

Large reproductions of figs. 10 and 11 may be obtained from the Bureau of Fisheries by persons having need of them.

and cippoletti weirs, respectively, for various heads. These charts are self-explanatory. Note that the flow over the cippoletti weir is directly proportional to the crest length minus a factor of the head or height of water on the weir. This is due to the end contractions caused by the vertical edges of the rectangular weir. The sloping ends of the cippoletti weir compensate for this end contraction.

For cippoletti weirs having a crest length other than one foot, the flow obtained from the chart should be multiplied by the crest length in feet. The chart may be used for a rectangular weir by multiplying the flow obtained from the chart by the factor $(L-0.017H)$, in which L is the crest length in feet and H is the head in inches, as shown in the accompanying illustrations. Example 1.—Assume a cippoletti weir having a crest length of 2.5 feet. The head of water flowing over the crest is 4.5 inches. Enter the chart at the left at reading 4.5. Follow horizontally to the right to intersection with diagonal. Then follow vertically downward to bottom where flow of 350 g. p. m. will be found. Multiply this by the crest length of 2.5, which gives a flow of 875 g. p. m. Example 2.—Assume a rectangular weir having a crest length of 2.0 feet. The head of water flowing over the crest is 3.5 inches. Enter the chart at the left at the reading 3.5. Follow horizontally to the right to intersection with diagonal. Then follow vertically downward to bottom where flow of 240 g. p. m. will be found. Multiply this by the factor $(L-.017H)=(2-.017\times3.5)=1.940$, which gives a flow of 465.6 g. p. m.

Channel velocity and cross-section method.—Where a stream channel is too large to conveniently install a weir, the next most accurate method is measurement of velocity by means of a current meter, and determination of the cross-sectional area by soundings. The average velocity in feet per second multiplied by the cross-sectional area in square feet will give the flow of the stream in cubic feet per second. Where a current meter is not available, a simple method of determining approximate velocity is to use a surface float. Simply throw a piece of wood into the middle of the stream at a fixed point and time its passage over a known distance of the stream. This method will give the surface velocity, which is usually from 1.05 to 1.33 times greater than the mean velocity, for the channel. Where the channel is not more than 2 feet deep the factor 1.33 should be used, and for channels 10 feet or more in depth the factor 1.05 should be used. Thus, for a deep channel, the average velocity would be considered equal to the measured surface velocity multiplied by 1.05 and for a shallow channel the average velocity would be equal to the surface velocity multiplied by 1.33. For intermediate depths proportional figures between these extremes should be used. In applying this method of measurement to cross-sectional areas in channels it is dsirable to select a section of the stream channel which is as smooth and uniform as possible. The cross-sectional area can be obtained by multiplying the width of the stream by the average depth. A simple way to obtain the average depth is to measure the depth of water at uniform intervals across the stream bed and divide the sum of such depths by the number of measurements plus 1.

BLANK FORMS FOR USE IN THE FIELD

DEPARTMENT OF COMMERCE

BUREAU OF FISHERIES

STREAM SURVEY

State River system Name of stream

Forest or park Map Number

County Tributary to

Stream section:

From:

To:

Length of section:

NOTES.—Sketches (show trails, roads, tributaries, stations, barriers, springs, etc.):

Name of stream Date

REGION	UPPER			MIDDLE			LOWER		
Station:									
Altitude									
Average width and depth									
Volume									
Velocity									
Color and turbidity									
Alkalinity									
pH									
Air temperature									
Water temperature									
Hour and sky									
Pools:									
Size, type, frequency	S	T	F	S	T	F	S	T	F
Caused by									
Shelter									
Bottom type:									
Pools									
Riffles									
Shade									
Aquatic vegetation									
Fish food (per sq. ft.):									
Caddisflies									
Mayflies									
Diptera									
Stoneflies									
Beetles									
Other insects									
Crustacea									
Miscellaneous									
Vol. in cc per sq. ft.									

Character of watershed: Canyons, mountainous, hilly, rolling, flat, swampy, wooded, open, cultivated, uncultivated.

Character of subsoil, bedrock and dip of strata.

Condition of stream: Low water, normal water, high water.

Fluctuation in volume:

Gradient:

Source:

Barriers (type, location, height):

Diversions (type, location):

Springs (location, volume, temperature):

Tributaries (number and size):

Fish (kinds, av. size, abundance, stations):

Enemies:

Degree fished (heavy, medium, light):

Spawning areas:

Fry, fingerlings seen (kinds, abundance, stations):

Accessibility of stream (by car or _____ miles by trail):

Previous stocking:

Pollution (source, type):

Rearing pool sites:

Fish recommended:

Species:

Reasons:

Remarks:

Improvements:

Investigator.

Average width: Pool grade: Food grade:

STOCKING PROGRAM

Section to be stocked:

Species:

Size:

Number:

Frequency:

Authority.

DEPARTMENT OF COMMERCE

BUREAU OF FISHERIES

LAKE AND POND SURVEY

State River system Name of lake

Forest or park Map

County Tributary to Number

NOTES.—Sketches (show soundings, stations, weed beds, tributary streams, outlet, roads, and trails on outline map):

N
↑

Name of lake: Date:

Altitude: Area:

Natural or artificial:

Height of dam: Fishway:

Character of shore line: Rocky, boggy, sandy, muddy, meadow, wooded.
Character of watershed: Mountainous, hilly, rolling, flat, swampy, wooded, open, cultivated, uncultivated.
Principal tributary streams (number and size):

Fluctuations in water level (causes and feet variation):

Approximate depth 100′ from shore _____, 200′ from shore _____,

Maximum _____

Shoal areas 20′ or less _____ % of lake:
Bottom—Mud, silt, sand, clay, peat, marl, detritus, hardpan, gravel, bedrock.
Deep areas: Bottom—Mud, silt, sand, clay, peat, marl, detritus, hardpan, gravel, bedrock.

Temperatures: Inlet _____, Outlet _____, Surface, _____, Air _____,

Hour _____, Weather _____

Color: Turbidity
Higher plants (show location on map): Abundance

Emergent:

Submerged:

Algae (kinds): Abundance

Vertebrates:

Kinds of fish: Abundance

Other vertebrates:

Invertebrates:

Shore (approx. no. per sq. ft.): Stoneflies ____, Mayflies ____, Caddisflies ____, Odonata ____, Diptera ____, Snails ____, Amphipods ____, Miscellaneous ____

OPEN WATER STATIONS	1	2	3	4	5
Depth in feet					
Plankton:					
Length of haul					
Quantity in cc					
Bottom (per ¼ sq. ft.):					
Midges					
Annelids					
Snails					
Clams					
Amphipods					
Miscellaneous					
Volume in cc					
Type of sample bottom					

Spawning areas:

Young fish seen:

Accessible by car or ____ miles by trail.

Boats available:

Pollution: Source:

Type:

Degree fished (heavy, medium, light):

Rearing pool sites:

Fish recommended:

Species:

Reasons:

Remarks:

Improvements:

Investigator.

STOCKING PROGRAM

Species:

Size:

Number:

Frequency:

Authority.

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